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The Relationship Between Plant Roots and Population Density of Soil Fauna in Some Vegetable Crops

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ABSTRACT

Soil is a complex environment resulting from the interaction between plant cultivated and soil fauna. In this work, we investigated the relationship between the chemical components of plant roots and the biodiversity of soil fauna. The effect of root exudates of three different vegetable crops (cucumber, okra and eggplant) on the activity density of soil fauna was compared. The experiment was carried out at Fayoum Governorate, Egypt. Soil arthropod samples were weekly taken from the aforementioned crops using the pitfall trap method. Also, the chemical composition of dry plant roots was examined. The following remarks are summarizing the obtained results: 1) total chemical composition of dry plant root material from okra was higher than cucumber and eggplant. 2) the total number of soil fauna collected from okra was (3799 indiv. /10 traps) decreased to (3312 &2220 /10 traps) in cucumber and eggplant, respectively. 3) These results show that root type and its chemical composition may affect the increase or decrease of soil fauna.

INTRODUCTION

Cucumber, *Cucumis sativus* L. (Family: Cucurbitaceae); eggplant, *Solanum melongena* L. (Family: Solanaceae); and okra, *Abelmoschus esculentus* L. (Family: Malvaceae); are among the important vegetable crops. Besides their nutritional value, they have great economic importance, especially cucumber and eggplant, which are grown commercially throughout the year, whether in the field or in greenhouses. These crops differ in the nature of their growth, whether the vegetative or root system and this has an impact on the diversity and density of pests and predators associated with these plants.

Soil fauna is a crucial constituent of biodiversity in the soil, and fundamental support for ecosystem functions (Zhang *et al*., 2022). They play paramount roles in plant litter decomposition (Soong *et al*., 2016). Also, the majority of soil fauna support plant growth by enhancing nutrient availability and repressing plant pests (Partsch *et al*., 2006; van Groenigen *et al*., 2014).

The activity of soil fauna and their interactions with each other results in an

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increase in the available nutrients that plants benefit from through root uptake (Carrillo *et al*., 2011). It also has an essential function in regulating microbial interactions in the rhizosphere zone, which greatly affects plant growth (Neagoe *et al*., 2014). On the other hand, there is positive correlation between the diversity of soil fauna and the variety of plants and modulates the spatial ecological conditions (Cifuentes-Croquevielle *et al*., 2020).

Soil fauna is an important source of biodiversity and plays a major role in several functions of soil ecosystem (Menta, 2012). The abundance and activity of the soil organism species can be influenced by vegetation type and structure. The soil community is most likely affected by the nutrient resources available and the diversity of microhabitats (Maharning *et al*., 2008). Moreover, plants act as a regulator of soil fauna through resource inputs, root exudates, and microhabitat modifications (Hooper *et al*., 2000; Wardle, 2005).

Rhizosphere is the area that includes the soil influenced by the roots, supporting various active groups of microorganisms (Geetanjali and Pranay, 2016). The pattern of the relationship between plant roots and soil fauna can take a variety of forms that may either support or suppress plant growth, often associated with interactions with soil micro-organisms (Menta 2012).

The chemical secretions of the roots serve as a food source for soil microbes, which in turn is a source of food, either directly or indirectly, for arthropods in the soil. However, soil fauna act a significant function in the interaction between soil microbes and plants (Nazir *et al*., 2016).

Furthermore, root exudates have a biological effect that is the chemical signals exchanged between plants and other soil organisms (Guerrieri *et al*., 2019). The concentration of soil organisms in the rhizosphere zone can be higher than 500 times than in the rest of the soil (Breure 2004).

Therefore, the major purpose of this work was to investigate the effect of plant type and chemical composition of roots on the population density of some arthropods in the soil.

MATERIALS AND METHODS

The experiment was undertaken at Ibshway, Fayoum Governorate, Egypt, during 2021 season. Three vegetable crops; cucumber, *C. sativus* L. (Cucurbitaceae); okra, *A. esculentus* L. (Malvaceae); eggplant, *S. melongena* L. (Solanaceae) were cultivated for this study.

The experiment area comprised ¼ feddan divided equally into three plots ($350m^2$ /crop), using Randomized Complete Block Design.

Sampling Method:

The soil arthropods were collected from the experiment area using the pitfall traps as described by Southwood and Henderson (2000). Number of soil fauna trapped is mainly dependent on population activity (Greenslade and Greenslade 1983; Kromp 1990; Mikhail 1993). These are consider activity densities rather than population densities (Kromp 1990) and are taken as individuals collected per trap (Mikhail and Hussein 1997).

Ten traps/plots cultivated were regularly applied weekly. The pitfall traps remained open for 24 hours. Obtained soil fauna was preserved in 75% ethyl alcohol, for inspection and identification.

Chemical Analysis of Roots:

Total Protein: An exact 10 ml of 0.5 N NAOH was added to 0.1 g oven-dry plant material and kept overnight. After filtration, water distilled was added to the extract to complete a 50 ml volume (Rousch 1981). A mix of 1 ml extract and 0.9 ml reagent A- [2 g potassium sodium tartrate, and 100 g sodium carbonate dissolved in 1000 ml of 0.1 N sodium hydroxide], then incubated in a water bath at 50 °C for 10 minutes. Following that the mixture was left to cool at room temperature, and 0.1 ml of reagent B- [2g potassium sodium tartrate and 1 g copper sulphate dissolved in 100 ml of 0.1N Sodium hydroxide] was added and mixed in a test tube. Then after 10 minutes, rapidly added 3ml of reagent C- [Folin 1 volume - Ciocalteu reagent diluted to 10 volume with distilled water] was with mixing using a vortex. Thereafter the tubes were incubated in a water bath at 50 °C for 10 min. Finally, the colour was spectrophotometrically measured at 650 Mm with reference to the known concentration of bovine serum albumin (Hartee1972).

Total Carbohydrate: Total carbohydrates were estimated by using anthrone method (Sadasivam and Manickam 1992).

Carbohydrates were extracted by hydrolyzing 0.5 g of plant powder with 5 ml 2.5 N HCL in a boiling tube in a boiling water bath for 3 hours. The mixture was left to cool down to room temperature and then, neutralized by adding sodium carbonate until the fizzing stopped. Distilled water was added to the extract to complete volume to 100 ml and centrifuged.

Exact 0.1 ml of the plant extract was pipetted into a test tube and distilled water was added to complete the volume to 1ml. The tube was submerged in a nice bath, 4ml of cold anthrone reagent was added and the tube was placed in a boiling water bath for 8 min. After rapidly cooling green colour was produced, and then measured spectrophotometrically at 630 Mm (Spectr UVS– 2700 / UVS –2800). The standard curve was prepared using different concentrations of glucose.

Mineral Analysis: The mineral ions Na, K, Ca, Mg and Fe were measured after ashing by atomic absorption (Model varian, Spectra AA220). Exact 0.5g dry plant powder was ignited in a muffle furnace at 600 °C for 8 hours and then cooled down in a vacuum desiccator. The ash was dissolved in loud nitric acid (0.1N)s and the volume was diluted to 100 ml with distilled water. The extract was measured on the atomic absorption following Chapman and Pratt (1961).

Functional group:

The breakdown of the trophy group is based on feeding strategies and methods of locomotion in the soil (Wallwork 1976); as soil arthropods eat their food, they mix up the soil.

Statistical Analysis:

Data were analyzed using the InfoStat computer software package (version, 2012). The differences among treatments were compared by LSD as a post hoc test at ≤ 5% level of significance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Chemical Composition of Dry Plant Roots:

Table (1) shows the chemical composition of dry plant roots. The total protein (% dry weight) in the roots of cucumber was (2.07) which increased to (3.07) in eggplant, but a large amount was found in okra roots (4.49).

Also, the total carbohydrate (% dry weight) in the roots of eggplant recorded (14.38) increased to (19.35) in cucumber roots, and the highest value (20.53) was found in okra roots.

In general, mineral composition (Na, K, Ca, Mg and Fe) (mg/g dry weight) in okra roots was higher than in cucumber and eggplant, except Mg in eggplant roots was more than in okra and cucumber. In addition, Ca was higher in cucumber than in okra and eggplant, respectively. Where total mineral composition (mg/g dry weight) in okra roots reached (37.44 mg/g) and cucumber recorded (37.11 mg/g), while the lowest value was found in eggplant root composition (31.38 mg/g). The highest value of individuals in okra may be due to root exudate.

Pollierer *et al*., (2007) and Fazaa (2021) reported that a great part of the food splay to soil fauna depended on the C-inputs from plant roots, while less C and nutrient inputs via plant litters.

Table 1: Chemical composition of dry plant roots of cucumber, okra and eggplant.

Chemical composition	Cucumber	Okra	Eggplant
Total protein (%dry weight)	2.07(0.64)	4.49 (0.69)	3.07 (0.79)
Total carbohydrates (%dry weight)	19.35(2.19)	20.53 (2.92)	14.38 (2.13)
Mineral composition (mg/g dry weight)			
Na	2.08(0.46)	2.16 (0.55)	1.94 (0.13)
K	19.05(2.61)	20.57 (3.18)	15.58 (2.77)
Ca	14.08(2.40)	11.68 (2.45)	10.06 (2.25)
Mg	0.86(0.13)	1.66 (0.47)	2.14 (0.49)
Fe	1.04(0.26)	1.37 (0.39)	1.66 (0.31)

Numbers between brackets are the standard errors (SE) of three replicates.

Dominance and Abundance of Soil Fauna:

Tables (2&3) show that the greatest number of collected individuals was found in okra (3799 individuals) decreased to (3312 indiv.) in cucumber and the lowest value was found in eggplant (2220 indiv.). Collembola, Formicidae, spiders and Carabidae respectively, were the most dominant soil fauna, also they were the most abundant when observed in the three crop fields throughout the season, Table (2). A similar result was found with Diptera and parasitoids, Table (3).

Soil mites depended on the content of total soil carbon and total nitrogen on soil types (Enami *et al*., 2000). Our data showed that the lowest number of soil mites found in okra cultivation (2 indiv.) increased to (9 indiv.) in cucumber, while the largest number (18 indiv.) was recorded in eggplant cultivation, Table (2).

The effect of the Root Zone on The Biodiversity of Soil Fauna:

The root system of the eggplant is characterized as weak in its early stages of growth. Many horizontal branches spread about 30-45 cm on the surface, and deep 7-20 cm into the soil. In ripe plants the root system is very outspread, about 300 roots often emerge in the surface foot of the soil, Most of these merely ramify the soil 20-35 cm from the plant.

Unlike eggplants, young plants of okra have strong taproots and numerous nearly equally long, mostly horizontal branches whose many laterals fill the surface of 20 cm of soil. Mature plants have taproots 5 cm thick and about 137 cm deep. The surface laterals become much thickened and extend widely, some to about 180 cm.

While in cucumbers, the roots have a single deep root and many shallow roots. Most of the branch roots reach 60 cm deep almost. Maturing plants have vines 4 to 6 feet (about 120-160 cm) long and a surface root system quite as extensive. In addition, the main laterals are exceedingly numerous and profusely branched in such a way as to quite occupy the soil (Weaver and Bruner 1927).

Table (2) shows that the highest number of Formicidae (979 indiv.) was found in okra and decreased to (157 indiv.) in eggplant, while a moderate number was found in cucumber (423 indiv.). There is a negative relation between existing Formicidae and plants that may result from an unoccupied composition between ant nesting sites and root zones (Parr *et al*., 2002; Rizk *et al*., 2017).

The fine roots in cucumber caused to found more Collembola (1797 indiv.) than in okra (1641 indiv.) and decreased to (1370 indiv.) in eggplant.

The biologically active soil zone between root-root, root-microbe, and root-insect communications, these interactions result in exudation (Walker *et al.*, 2003). Since root tips are the major sites of root exudation (Fazaa 2021).

Table 2: Population, dominance (D%) and abundance (A%) of certain arthropods collected from cucumber, okra and eggplant fields during 2021 season.

Crop	Cucumber									Okra									Eggplant								
Date	Spiders	Collembola	Carabidae	Formicidae	Isopoda	Labiduridae	Gryllidae	Soil mites	Total	Spiders	Collembola	Carabidae	Formicidae	Isopoda	Labiduridae	Gryllidae	Soil mites	Total	Spiders	Collembola	Carabidae	Formicidae	Isopoda	Labiduridae	Gryllidae	Soil mites	Total
09/03/2021	4	47	8	3	0	0	0	0	62	2	25	4	25	0	0	1	0	57	3	48	2	9	0	0	0	0	62
16/03/2021	4	39	5	6	0	0	0	0	54	4	54	2	31	0	1	0	0	92	2	46	9	3	0	0	0	0	60
23/03/2021	10	112	12	31	0	0	0	0	165	8	126	6	19	0	0	1	0	160	5	67	11	15	0	1	0	0	99
30/03/2021	5	89	10	24	0	0	0	0	128	7	109	7	55	1	1	0	0	180	9	41	7	13	0	0	1	0	71
06/04/2021	6	78	11	41	0	0	0	0	136	16	143	16	47	0	3	0	0	225	8	69	4	8	0	0	0	0	89
13/04/2021	4	82	7	11	1	1	0	0	106	16	125	10	19	0	0	0	0	170	6	76	7	11	0	0	0	0	100
20/04/2021	25	74	10	42	0	0	0	1	152	27	108	4	83	1	0	0	0	223	9	31	5	3	0	2	0	0	50
27/04/2021	15	42	4	9	0	2	1	0	73	19	36	2	24	0	0	0	0	81	5	17	1	9	0	0	0	0	32
04/05/2021	21	86	6	43	0	0	0	0	156	28	98	8	56	0	3	2	0	195	16	93	2	11	1	4	1	3	131
11/05/2021	17	64	4	21	0	3	1	3	113	26	154	12	71	0	4	1	1	269	10	69	8	2	0	3	0	0	92
18/05/2021	31	211	15	33	1	2	0	2	295	34	112	7	42	2	4	3	0	204	15	143	2	14	0	9	1	4	188
25/05/2021	34	223	22	59	0	4	0	0	342	40	175	20	131	0	3	1	1	371	12	92	7	3	0	8	0	2	124
01/06/2021	46	241	19	27	0	4	0	3	340	57	127	13	169	0	4	0	0	370	23	165	3	17	1	6	3	5	223
08/06/2021	28	211	12	32	0	2	0	0	285	49	146	8	93	1	1	0	0	298	32	197	4	25	0	4	2	3	267
15/06/2021	35	198	24	41	0	3	0	0	301	41	103	17	114	0	3	0	0	278	39	216	9	14	0	4	0	1	283
Total	285	1797	169	423	2	21	2	9	2708	374	1641	136	979	5	27	9	2	3173	194	1370	81	157	2	41	8	18	1871
D%	10.5	66.4	6.2	15.6	0.1	0.8	0.1	0.3		11.8	51.7	4.3	30.9	0.2	0.9	0.3	0.1		10.4	73.2	4.3	8.4	0.1	2.2	0.4	1.0	
A%	100	100	100	100	13.3	53.3	13.3	60.0		100	100	100	100	26.7	66.7	40.0	13.3		100.0	100	100	100	13.3	60.0	33.3	40.0	

Table 3: Population, dominance (D%) and abundance (A%) of other arthropods collected from cucumber, okra and eggplant fields during 2021 season.

Crop	Cucumber						Okra						Eggplant					
Sampling date	Parasitoids	Diptera	Aphids	Whiteflies	Jassids	Total	Parasitoids	Diptera	Aphids	Whiteflies	Jassids	Total	Parasitoids	Diptera	Aphids	Whiteflies	Jassids	Total
09/03/2021	7	39	0	2	0	48	8	29	3	1	0	41	4	11	0	1	3	19
16/03/2021	5	48	0	3	0	56	13	22	1	0	0	36	14	19	8	3	0	44
23/03/2021	16	39	21	7	8	91	18	7	5	4	0	34	16	27	11	2	5	61
30/03/2021	9	24	6	2	3	44	33	38	12	9	7	99	7	15	0	0	0	22
06/04/2021	15	31	7	0	2	55	11	12	8	0	2	33	3	23	0	1	1	28
13/04/2021	8	16	3	2	0	29	18	23	11	0	5	57	7	16	4	0	2	29
20/04/2021	12	12	2	0	6	32	12	19	14	5	3	53	2	11	0	1	0	14
27/04/2021	3	9	9	0	4	25	3	8	6	0	8	25	1	3	0	0	0	4
04/05/2021	11	18	5	0	3	37	9	17	8	2	4	40	8	8	2	1	4	23
11/05/2021	9	13	0	3	2	27	7	27	0	0	2	36	9	13	2	0	3	27
18/05/2021	12	17	0	0	9	38	13	13	0	5	1	32	5	9	5	0	5	24
25/05/2021	16	21	0	0	7	44	24	9	3	2	4	42	6	8	0	1	0	15
01/06/2021	7	15	0	0	4	26	21	18	0	0	2	41	6	2	0	2	3	13
08/06/2021	9	11	0	0	2	22	9	23	0	0	0	32	4	9	0	0	0	13
15/06/2021	3	22	0	0	5	30	12	11	0	0	2	25	7	5	0	0	1	13
Total	142	335	53	19	55	604	211	276	71	28	40	626	99	179	32	12	27	349
D%	24.00	55.46	8.77	3.15	9.11		33.71	44.10	11.34	4.47	6.39		28.37	51.29	9.17	3.44	7.74	
A%	100	100	47	40	80		100	100	67	47	73		100	100	40	53	60	

Functional Group:

This study indicated that chemical root exudates and rhizosphere reactions permit the prediction of species richness, and its effect on the functional group. Studies of soil fauna biodiversity and its functional group can therefore be a good indicator of the relation between crop cultivations and its root exudates. Accordingly, we found that okra root exudates more protein (4.49), carbohydrates (20.53) and total mineral (mg/g) (37.44), caused detritivores (2896 indiv.), predators (537 indiv.), herbivores (148 indiv.) and parasitoids (211 indiv.). While the same arthropods were (2555, 475, 129 & 142 indiv.) and (1706, 316, 79 & 99 indiv.) in cucumber and eggplant respectively, Table (4).

Table 4: Breakdown of soil surface arthropods captured by pitfall traps into trophy groups.

Taxa	Cucumber		Okra		Eggplant	
	No.	Total	No.	Total	No.	Total
Detritivores						
Collembola	1797	2555	1641	2896	1370	1706
Formicidae	423		979		157	
Diptera	335		276		179	
Carnivores						
Spiders	285	475	374	537	194	316
Carabidae	169		136		81	
Labiduridae	21		27		41	
Herbivores						
Aphids	53	129	71	148	32	79
Jassids	55		40		27	
Whiteflies	19		28		12	
Gryllidae	2		9		8	
Parasitoids	142	142	211	211	99	99
Soil mites	9	9	2	2	18	18
Isopoda	2	2	5	5	2	2
Total	3312		3799		2220	

Difference between Cucumber, Okra and Eggplant for the Occurrence of Some Arthropods in Soil:

As shown in Table (5) Collembola was the most common arthropod with a mean (119.80), but spiders were found with a high number in okra (24.93) than in cucumber (19.00) and eggplant (12.93). Generally, the density of spiders increases as the size and complexity of the plant structure increases, and therefore the small plant hosts harbor fewer numbers of spiders than the abundantly growing and structurally complex hosts (Liu *et al*., 2003).

Table 5: Difference between cucumber, okra and eggplant for occurrence of some arthropods in soil.

Arthropods	Cucumber	Okra	Eggplant	LSD (5%)
Spiders	19.00b ±3.53	24.93a± 4.34	12.93c± 2.77	4.68
Collembola	119.80a± 19.09	109.40a± 10.99	91.33a± 15.78	29.01
Carabidae	11.27a± 1.63	9.07a± 1.43	5.40b± 0.80	3.02
Formicidae	28.20b± 4.14	65.27a± 11.63	10.47b± 1.63	18.7
Isopoda	0.13a± 0.09	0.33a± 0.16	0.13a± 0.09	0.33
Labiduridae	1.40b± 0.40	1.80ab± 0.43	2.73a± 0.79	1.07
Gryllidae	0.13a± 0.09	0.60a± 0.24	0.53a± 0.24	0.59
Soil mites	0.60ab± 0.29	0.13b± 0.09	1.20a± 0.45	0.80

Means with a common letter are not significantly different t($p > 0.05$).

While the mean number of Carabidae in cucumber reached (11.27) more than in okra (9.07) and eggplant (5.40). The highest number of Formicidae was recorded in okra with a mean number of (65.27) more than in cucumber (28.20), however, the lowest number was found in eggplant with a mean number of (10.47).

According to these results, it is clear that eggplant harbored fewer soil arthropods compared to okra and cucumber plants. This may be due to the type of plant and its root growth system, as well as to the secretions of these roots and their chemical composition.

From these results, we can conclude that the diversity, density and abundance of soil fauna can be greatly affected by the different types and compositions of the plant host. Sanderson *et al*., (2020) compared the abundance of invertebrates in different vegetation plots, their results showed that the various vegetation habitats can support the high diversity and abundance of invertebrates. The soil community abundance and diversity can be influenced by the plant type and structure. (Maharning *et al*., 2008). Chiriac et al., (2020) mentioned in a brief review of the relationship between plants and soil invertebrates, that the relationship between plants and soil organisms is probable to be dynamic, depending on plant growth, and the density, activity and behavior of soil invertebrates.

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ARABIC SUMMARY

العلاقة بين جذور النباتات وكثافة التعداد لحيوانات التربة في بعض محاصيل الخضر

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التربة بيئة معقدة ناتجة عن التفاعل بين النباتات المزروعة وحيوانات التربة .في هذا العمل ، تم دراسة العلاقة بين المكونات الكيميائية لجذور النباتات والتنوع البيولوجي لحيوانات التربة . .أجريت التجربة بمحافظة الفيوم بمصر على ثلاثة محاصيل خضر مختلفة هي الخيار والبامية والباذنجان .تم أخذ عينات من مفصليات الارجل في التربة أسبوعياً من المحاصيل المذكورة أعلاه باستخدام طريقة المصائد الارضية .كما تم تحليل التركيب الكيميائي للجذور الجافة لهذه النباتات. تمت مقارنة تعداد وكثافة حيوانات التربة .وتلخص الملاحظات التالية النتائج التي تم الحصول عليها: 1) كان التركيب الكيميائي الكلي لجذور نباتات البامية أعلى من الخيار والباذنجان (2 .بلغ التعداد الإجمالي لحيوانات التربة التي تم جمعها من البامية (3173 فصيلة / 10 مصائد) وانخفض إلى (2708 و 1871/10 مصائد) في الخيار والباذنجان على التوالي (3 .تظهر هذه النتائج أن نوع الجذر وتركيبه الكيميائي يمكن ان يؤثر على تعداد وتنوع ووفرة حيوانات التربة.

الكلمات الدالة: حيوانات التربة، نوع الغطاء النباتي، تركيب المجموع الجذري، التركيب الكيميائي.